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(12) **Patent:**

(11) **CA 2114583**

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(54) **WASTE ACTIVATED SLUDGE TREATMENT SYSTEM**

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(54) **SYSTEME DE TRAITEMENT DE BOUES BIOLOGIQUES ACTIVEES**

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### ABSTRACT:

A process and apparatus to promote rupturing and destruction of biological cell walls for solubilization of biological sludge is provided. The process involves concentrating a sludge above an initial concentration by an

evaporation process at the saturation temperature for the operating pressure, and a high shearing process applied to the concentrated solids. The invention also provides an apparatus to promote rupturing of biological cell walls for the destruction and solubilization of biological sludge, the apparatus with an evaporation region for concentrating sludge, a shearing region for rupturing the biological cell walls, and a sump region for receiving a feed stream of sludge and discharging a dewatered product stream. The process also provides a retention time for the destruction and solubilization to take place and provides for the separation of water from the sludge for re-use.

CLAIMS: [Show all claims](#)

\*\*\* Note: Data on abstracts and claims is shown in the official language in which it was submitted.

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## Canadian Patent Database

04/26/2000 - 10:56:40

**Patent Document Number 2114583 :**
**WASTE ACTIVATED SLUDGE TREATMENT SYSTEM**
**SYSTEME DE TRAITEMENT DE BOUES BIOLOGIQUES  
ACTIVEES**

## CLAIMS:

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A process to promote rupturing of biological cell walls for destruction and solubilization of biological sludge comprising the steps of:
  - a) concentrating the biological sludge by an evaporation process in an apparatus to effect concentration of the biological sludge; and,
  - b) subjecting the sludge to a high shearing process to effect destruction and solubilization of the biological sludge; wherein the evaporation and shearing processes are a repeating cycle with controlled addition of a feed stream and removal of a product stream.
2. A process as in claim 1 wherein the evaporation process is a falling film evaporation process.
3. A process as in claim 1 wherein the high shearing process is a rapid decompression process.
4. A process as in claim 1 wherein the high shearing process is preceded by a mechanical shearing process.
5. A process as in claim 1 wherein non-condensable gases formed

during the evaporation process are vented.

6. A process as in claim 1 wherein the evaporation process concentrates the sludge by a factor of 2:1 to 75:1 with respect to the concentration of the feed stream.

7. A process as in claim 1 wherein the process pH is controlled by a chemical additive.

8. A process as in claim 1 wherein the evaporation process is a falling film evaporation process in a shell and tube heat exchanger.

9. A process as in claim 8 wherein energy for the evaporation process is provided by steam on the shell side of the heat exchanger.

10. A process as in claim 8 wherein the evaporation process includes compressing and combining process steam formed from the evaporation process with make-up steam for reintroduction to the shell side of the heat exchanger.

11. A process as in claim 9 wherein the evaporation process includes utilizing distillate heat from the shell side of the heat exchanger for pre-heating the feed stream.

12. A process to promote rupturing of biological cell walls for destruction and solubilization of biological sludge in an apparatus having a sump region, shearing region and heating region, comprising the steps of:

- a) providing a feed stream of biological sludge to the sump region;
- b) providing a circulation stream of biological sludge from the sump region to the shearing region;
- c) subjecting the circulation stream to shearing in the shearing region to effect shearing of the biological sludge;
- d) providing the circulation stream to the heating region to effect concentration of the biological sludge by an evaporation process;
- e) returning the circulation stream to the sump region for mixing and settling;
- f) removing a product stream from the sump region.

13. A process as in claim 12 wherein concentration of the biological sludge is by a falling film evaporation process.

14. A process as in claim 12 wherein shearing of the biological sludge is by a rapid decompression process.

15. A process as in claim 14 wherein the rapid decompression

process is preceded by a mechanical shearing process.

16. A process as in claim 12 wherein non-condensable gases formed during concentration of the biological sludge are vented.

17. A process as in claim 12 wherein the concentration of the biological sludge in the heating region is 2:1 to 75:1 with respect to the concentration of the feed stream.

18. A process as in claim 12 wherein the process pH is controlled by a chemical additive.

19. A process as in claim 12 wherein concentration of the biological sludge is a falling film evaporation process in a shell and tube heat exchanger.

20. A process as in claim 19 wherein energy for the heat exchanger is provided by steam on the shell side of the heat exchanger.

21. A process as in claim 19 wherein the evaporation process includes compressing and combining process steam formed from the evaporation process with make-up steam for reintroduction to the shell side of the heat exchanger.

22. A process as in claim 19 wherein the evaporation process includes utilizing distillate heat from the shell side of the heat exchanger for pre-heating the feed stream.

23. A process to promote rupturing of biological cell walls for destruction and solubilization of biological sludge in an apparatus having a sump region, mechanical shearing region, decompressive shearing region and heating region, comprising the steps of:

- a) providing a feed stream of biological sludge to the sump region;
- b) providing a circulation stream of sludge from the sump region to the mechanical shearing region to effect mechanical shearing of the sludge;
- c) providing the circulation stream of sludge from the mechanical shearing region to the decompressive shearing region to effect decompressive shearing of the sludge;
- d) providing the circulation stream to the heating region to effect concentration of the sludge through a falling film evaporation process;
- e) venting non-condensable gases from the evaporation process;
- f) returning the circulation stream to the sump region for mixing with the feed stream and settling of solubilized biological sludge;
- g) removing a product stream of solubilized biological sludge from the sump region.

24. An apparatus to promote rupturing of biological cell walls for destroying and solubilizing biological sludge comprising: an evaporation region for concentrating sludge; a shearing region for shearing sludge; a sump region having means for receiving a feed stream of sludge and means for discharging a product stream; means for circulating sludge between the sump region, shearing region and evaporation region.

25. An apparatus to promote rupturing of biological cell walls for destroying and solubilizing biological sludge comprising a sump region, a shearing region and a heating region: the sump region having means for receiving and containing a feed stream of the sludge, means for discharging a product stream of suspended solids, means for discharging a circulation stream of sludge to the shearing region and means for receiving a sludge concentrate from the heating region; the shearing region having means for receiving the circulation stream from the sump region, means for subjecting the biological sludge to rapid decompression and means for distributing decompressed sludge to the heating region; the heating region having means for concentrating the sludge from the shearing region by falling film evaporation and means for returning a concentrated sludge to the sump region; where the sludge is cycled between the sump region, shearing region and heating region.

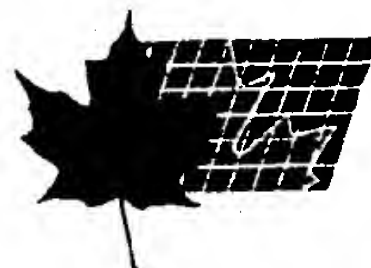
26. The apparatus as in claim 25 wherein the sump region has an inwardly tapered region at the lower end of the sump region for funnelling the sludge to a product discharging port.

27. The apparatus as in claim 25 wherein the means for concentrating the sludge from the shearing region by falling film evaporation and means for returning a concentrated sludge to the sump region are a shell and tube heat exchanger.

28. The apparatus as in claim 25 where the shearing region is provided with a spray nozzle to enhance rapid decompression of the sludge.

29. The apparatus as in claim 25 further comprising means for venting vapour produced in the heating region.

30. The apparatus as in claim 27 further comprising means for compressing and heating vapour from the heating region for heating the shell side of the heat exchanger.



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(19) (CA) **CANADIAN PATENT** (12)

(54) **Waste Activated Sludge Treatment System**

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(73) **Same as inventor**

(57) **30 Claims**





**WASTE ACTIVATED SLUDGE TREATMENT SYSTEM**

The present invention relates to a process and apparatus for destroying and solubilizing biomass.

5

**BACKGROUND OF THE INVENTION**

Activated Sludge Treatment (AST) is a proven method of reducing the BOD<sub>5</sub> and toxicity of most common effluents. By creating an environment in the effluent where selected microorganisms can exist, biodegradable  
10 contaminants in the effluent are converted to carbon dioxide gas (CO<sub>2</sub>), water and microorganisms. The bodies of the microorganisms often referred to as biomass, are comprised mostly of water, with minor amounts of organic and inorganic compounds. The microorganisms remain suspended as Mixed Liquor Suspended Solids (MLSS) and are carried to a separation device such as a  
15 gravity clarifier for return to the aeration basin and wasting. Separation of the biomass from the treated effluent in a gravity clarifier produces a low consistency waste activated sludge (WAS) which is removed from the AST system for further processing in dewatering equipment. The low mass and the repulsion caused by the high anionic charge of the microorganisms keeps them  
20 dispersed in the liquid. With the use of modern clarifiers, the biomass can be thickened to a manageable volume, and the clarified water is discharged to the receiving water body in an acceptable condition.

The excess microorganisms must be continuously removed from the  
25 AST system to keep the Mixed Liquor Suspended Solids (MLSS) within a control range. The sludge containing the biomass is difficult to dewater as the majority of the liquid is tightly bound within the body of the microorganisms. To remove this liquid the cell wall must be broken and the liquid within drained. In the past, attempting this with mechanical equipment has given  
30 limited results. In a typical operation, up to 0.8 tonnes of sludge are produced for each tonne of BOD<sub>5</sub> removed in the effluent treatment plant. In the pulp





and paper industry, 0.4 to 0.5 tonnes of biological sludge may be produced for each tonne of BOD<sub>5</sub> removed.

5       The typical sludge consistencies of 0.5 to 2 weight percent from the secondary clarifier require substantial quantities of water to be removed. Sludge presses apply mechanical energy to assist dewatering. With this method of dewatering, the equipment drainage holes are prone to plugging due to the colloidal nature of the sludge. Furthermore, the sludge often flows through the openings when excessive mechanical energy is used to force more water  
10       from the sludge, contaminating the filtrate.

      Charge neutralization chemicals can be used to overcome the repulsion of the biomass and polymers bind the solids together in flocs allowing the water to drain more freely from the area around the sludge. Despite  
15       improvements from chemical addition, the sludge dryness from mechanical devices such as the sludge press remains low. With typical consistencies of 15% - 20% solids after initial mechanical sludge dewatering, the final mass of sludge to be disposed of is typically 5-6 times greater than fully dried sludge.

20       As well, excessive quantities of water are often carried off with the sludge for disposal. In order to reduce this quantity of water, sludge drying following mechanical dewatering is sometimes utilized. By employing heat, moisture is driven off, drying the sludge and reducing the quantities for disposal.

25       The chemical costs for WAS dewatering, coupled with disposal fees, are the largest expense that some industries incur for effluent treatment. Drying to acceptable consistencies consumes valuable resources and increases operating costs. Failing to dry the sludge increases trucking costs and tipping  
30       fees for hauling water to the landfill site.

Compounding the operating difficulties of sludge dewatering are new regulatory criteria for the disposal of sludge which are being imposed on many facilities.

5 Past processes have been limited in effectiveness and efficiency by requiring various chemicals to effect rupturing of cell walls and/or to inhibit agglomeration.

10 United States Patent 5,087,378 discloses a process for enhancing the dewaterability of waste sludge from microbial digestion. This process involves heat treatment of a sludge with a solids content of at least about 15 weight % and requires the use of pH adjusting chemicals.

15 United States Patent 5,232,604 describes a process for the oxidation of materials in water at supercritical temperatures utilizing reaction rate enhancers. This process requires strong oxidizing agents and preferred temperatures in the range of 500° to 800°C.

20 United States Patent 4,119,495 describes a process for hydrolysing activated sludge at an acidic or alkaline pH at moderate temperatures. This process requires pH adjusting chemicals.

25 United States Patent 4,240,904 describes a process for biological purification of waste water in the presence of a volatile base at a temperatures between about 90° and 300°C.

United States Patent 4,988,442 describes a pressure and temperature treatment process for dewatering biological sludge with centrifugation, chemical conditioning of isolated solids and dewatering.

30 There is, therefore, a need for new methods for the treatment and disposal of waste activated sludge as conventional handling methods are

difficult and are producing products becoming less acceptable for landfill or for land-spreading.

Specifically, there has been a need for a new process and apparatus that  
5 provides effective treatment of biomass without the use of chemicals that  
enables disposal through physical disruption and evaporative concentration of  
the biomass to produce a soluble, biodegradeable product in order to reduce  
quantities of sludge requiring landfill. Furthermore, there has been a need for  
a process that has a high system efficiency and recovers high purity water for  
10 reuse.

**SUMMARY OF THE INVENTION**

In accordance with the invention, there is provided a process to promote rupturing of biological cell walls for destroying and solubilizing biological sludge comprising the steps of:

- 5       a) concentrating the biological sludge above an initial concentration by an evaporation process at the saturation temperature for the operating pressure;
- b) subjecting the sludge to a high shearing process.

10       In an alternate embodiment, the process includes controlled addition of a feed stream and removal of a product stream. The evaporation process may be a falling film mechanical vapour recompression evaporation process or falling film cascade evaporation process and the high shearing process may be rapid decompression of the sludge optionally preceded by mechanical shearing.

15

         In another embodiment, non-condensable gases from the evaporation process may be vented resulting in the pH of the biological sludge being raised naturally.

20

         In a preferred embodiment, falling film evaporation is conducted in a shell and tube heat exchanger with energy for evaporation provided by steam on the shell side of the heat exchanger. The distillate formed on the shell side of the heat exchanger may be used in a primary heat exchanger for preheating

25       the sludge to improve efficiency. Process steam generated from the evaporation process may be compressed and combined with fresh steam under some conditions such as start-up. Non-condensable gases are vented from the shell side of the heat exchanger.

30

         In still another embodiment, the evaporation process provides a concentration factor in the range of 2:1 to 75:1 with a saturation temperature

of 50°C to 200°C and a retention time of 15 minutes to 12 hours in the repeating cycle to allow solubilization and destruction to take place.

5 In another embodiment, the pH of the process is controlled by a chemical additive.

10 In still another embodiment, the product is further subjected to organic and inorganic separation where soluble organics are returned to an effluent treatment plant for further processing. Similarly, the distillate may be returned for re-use in place of fresh water.

15 The invention also provides an apparatus to promote rupturing of biological cell walls for destroying and solubilizing biological sludge comprising an evaporation region for concentrating sludge, a shearing region for rupturing the biological cell walls, and a sump region for receiving a feed stream of sludge and discharging a dewatered product stream.

#### BRIEF DESCRIPTION OF THE DRAWINGS

20 These and other features of the invention will become more apparent from the following description in which reference is made to the appended drawings wherein:

FIGURE 1 is a flow diagram of an activated sludge treatment process showing a conventional treatment and the process according to the invention;

25 FIGURE 2 is a cutaway diagram of the sludge digestion apparatus according to the invention;

FIGURE 3 is a elevation of a sludge digestion plant according to the invention;

FIGURE 4 is a plan view of a sludge digestion plant according to the invention;

30 FIGURE 5 is a graph of the results of Scan #1 for a 2:1 volume reduction showing the effect of caustic addition to total suspended solids and final pH.

**FIGURE 6** is a graph of the results of Scan #2 for a 5:1 volume reduction showing the effect of caustic addition to total suspended solids and final pH.

5

### **DESCRIPTION OF PREFERRED EMBODIMENT**

The sludge treatment process and apparatus 30 according to the invention may form a component in a conventional activated sludge treatment system (Figure 1). In an AST process, a plant 10 produces effluent 12 with a primary solids content. Treatment of the suspended solids and BOD<sub>5</sub> may be initiated in a primary clarifier 14, aeration basin 16 and secondary clarifier 18 to produce a low consistency waste activated sludge 20. In a conventional process, the return activated sludge 19 may be recycled to the aerated basin 16 and secondary clarifier 18. The primary sludge from the primary clarifier 14 and the secondary sludge from the secondary clarifier 18 may also be blended in a sludge tank 22 before passing the sludge through a sludge press 24 to remove water around the biomass.

20

The sludge treatment process and apparatus 30 according to the invention utilizes the waste activated sludge 20 from the above process to provide a concentrated, solubilized biomass product 22 for separation into organic 24 and inorganic 26 components. Separation may be conducted in a separator 28. The sludge treatment apparatus (STA) 30 further provides recovered water for return to the plant 10 for re-use.

25

The sludge treatment apparatus (STA) 30 (Figure 2) receives waste activated sludge 20 as a dilute slurry of suspended solids (typically up to 6 wt% suspended solids and 0.5-1.5 wt% dissolved solids) into a sump portion 32. The sludge is heated to the saturation temperature (typically 50°C to 200°C) at the operating pressure. The sludge is mixed with the circulating sludge liquor solution within the STA 30 which is in varying stages of decay.

30

The volume of liquid within the sump 32 is maintained to provide an appropriate residence time (typically 15 min to 12 hours depending on the sludge composition and the operating temperature, pressure, sump concentration and pH) necessary for adequate destruction. Product 22 is removed from the bottom of the sump 32 for transport to separator 28. Sludge in the sump 32 is simultaneously cycled through the apparatus 30 through a circulation stream 34. The circulation stream 34 may be provided with a high shear device 36 to subject the concentrated sludge to high shearing forces to provide an initial action of mechanical destruction of the suspended solids within the sludge. The sludge is pumped under pressure to the top of the STA 30 where it may be subjected to rapid decompression in the decompression portion or flood box 38 of the STA 30 for further shearing.

The rapid decompression bursts intact cells by subjecting the cell membranes to high differential pressures thereby releasing trapped fluid within the cells. A nozzle 40 may be provided to enhance the dispersion and destruction of the sludge by decompression.

The decompressed sludge is then passed to the tube side of a shell and tube heat exchanger forming the heating portion 42 of the STA 30. The sludge falls by gravity to the sump 32 during which the sludge is concentrated by falling film evaporation along the length of the tubes 43, thereby forming a concentrate. The typical diameter of the tubes is 1 to 2 inches. Heat for the falling film evaporation is provided by saturated steam from the shell side of the heat exchanger 42. Heat is transferred through the tube walls from the shell side of the heating portion 42. The steam condenses on the outside tube surface and is drawn off as distillate 43. The transferred heat causes boiling within the concentrate inside the tube, driving off process steam. Process steam from the upper section is ducted downwardly to the sump 32 via down pipe 44. Gases and vapour above the gas/liquid interface within the sump are demisted by a demister (not shown) and passed to compressor 46. Fresh make-up steam 48 may be injected for some operating conditions



such as during start-up. The compressed steam is introduced to the shell side of the heat exchanger 42 to supply energy for further evaporation of the concentrate within the tubes. Non-condensable gases are vented from the shell side of the heat exchanger through vent 50. The effect of venting non-  
5 condensable gases, which include carbon dioxide, results in a natural increase in the pH of the system which coupled with the elevated temperature promotes breakdown of the biomass. The effects of temperature, increased pH and concentration, ensure that the shearing forces applied to the solution are more effective in the mechanical destruction of the suspended solids within the  
10 sludge.

Chemical additives may be optionally added to the system to either elevate or decrease the pH of the liquor in the system to an optimal level in order to assist solubilization of the biomass. The pH range may be 1 to 13  
15 depending on the specific biomass being treated. The use of sodium containing pH chemicals is preferably avoided to prevent excessive sodium ion concentrations in the product produced.

The thickened or concentrated sludge from the heating portion  
20 42 falls to the sump where a sufficient retention time is provided for destruction of the biomass. The concentrate is comprised of sludge in various stages of degeneration. Concentration factors may typically range from 2:1 to 75:1 depending on the specific biomass being treated.

25 The cycle is repeated with virtually full transfer of latent heat creating a highly energy efficient process. Distillate 43 formed within the shell side of the heat exchanger 42 is collected at the bottom of the heat exchanger 42 and may be further used in a feed heat exchanger (not shown) for heating the sludge 20 before entering the sump 32 in order to improve the energy efficiency of the  
30 system. The distillate 43 produced is a beneficial byproduct and is available for mill or plant 10 use as high quality make-up water for such services as boiler feedwater.

Product 22 is drawn off at a reduced volume compared to the feed volume to keep the suspended solids within a control range. From this product the inorganic suspended solids are removed by a separation device and dewatered. Dissolved solids are returned to the AST system.

Figures 3 and 4 show an elevation and plan view of a typical STA installation.

## 10 Control of System

Control of the process is provided by conventional flow, pressure, temperature, level and pH indicators. Control of feed 20 into the sump 32 is provided by flow indicator 60, valve 62 and level indicator control 64. The temperature of circulation stream 34 is monitored by temperature indicator 66. Control of the shell side steam pressure and temperature is provided by pressure indicator 70, valve 72, temperature indicator 74, control valve 76, temperature indicator 78, and valve 80. Flow indicator 82 and valve 84 control the gas/vapour to the compressor 46. Venting of non-condensable gases is controlled by valve 86. Product removal may be controlled by flow indicator 88 and valve 90. It will be appreciated by those skilled in the art that numerous control strategies are possible to effect control of the process and apparatus.

## 25 Experimental Results

Single stage biological sludge destruction efficiencies in excess of eighty percent (80%) have been experienced in laboratory experiments of the STA. The Sludge Destruction Efficiency (SDE) is defined as:

$$30 \quad SDE = \frac{\text{Volatile Suspended Solids In} - \text{Volatile Suspended Solids Out}}{\text{Volatile of Suspended Solids In}}$$

The STA 30 dissolves biological suspended solids in the waste activated sludge and the product is returned to the AST system, where the dissolved organics are metabolized to carbon dioxide gas ( $\text{CO}_2$ ), water, and a reduced quantity of new biomass. Through repetition of the sludge treatment process by recycling to the AST, overall sludge reduction efficiency of the system approaches 100% as described by Springer et al in their paper "Feasibility Study of Sludge Lysis and Recycle in the Activated Sludge Process", Tappi Environmental Conference, 1993, pages 761-771. The end result is a dramatic reduction in the amounts of excess biological sludge for handling and disposal.

10

The STA was proven in a bench scale unit. Comprised of a heating flask, agitation and a condensible column the unit can continuously process waste activated sludge at a rate of 300 mls/hour. From this apparatus sufficient product was generated for testing.

15

#### Examples

Waste activated sludge samples were obtained from a northern Alberta CTMP mill. Trials were run to investigate the ability of the benchtop STA unit to solubilize Chemical Oxygen Demand (COD), nitrogen (measured as Total Kjeldahl Nitrogen [TKN]), and total phosphorus (measured as Total Phosphates); while lowering the overall Total Suspended Solids (TSS) of the treated biomass. The COD and conductivity of the distillate was tested to establish suitability for re-use.

20

Waste Activated Sludge (WAS) was run through the STA simulator at an alkaline pH of 8, measured using Fisher Scientific (Edmonton, AB) Accumet #915 pH meter. Standard COD, TKN, Total Phosphate (TP), Conductivity, Carbonates, Sulphates, heating value and TSS tests were performed on the raw WAS and treated sludge products according to American Public Health Association (APHA) approved standard procedures.

25

30

CODs were obtained using a colorimetric method (Hach DR/2000 Spectrophotometer, Loveland, CO). Filtered and unfiltered samples were tested for the raw and treated samples. Three scans were performed to evaluate the effect of sludge treatment under different conditions.

5

#### Scan 1

Five one liter samples were heated and boiled for 2 hours using hot plates and beakers. Varying quantities of NaOH were added, from 0 to 4000 mg/l. The samples were reduced to 60% of original volume after about 2 hours of boiling. The TSS of the remaining solution were measured.

10

#### Scan 2

Four biomass samples with caustic addition rates varying from 230 to 900 mg/l were boiled and reduced to approximately 20% of their original volume in about 4 hours. Hot plates and 1000 ml beakers were used, and there was no collection of distillates for this trial.

15

#### Scan 3

One liter of well-mixed unfiltered biomass was distilled in a three-necked round bottom flask equipped with mechanical stirrer and condenser. Distillate was collected in several fractions and stored in a fridge for further analyses. At the end of the run, the volume remaining in the sump was determined. The solution was transferred to a 250 ml glass bottle and stored in a fridge.

20

25

### Results

#### Scan 1

The effects of varying concentrations of caustic addition to TSS reduction and final pH were demonstrated, and are summarized in Figure 5. As the NaOH concentration increased from 0 to 4000 mg/l, the final mass of

30

TSS decreased from 6510 to 3954 mg. and the pH increased from 9.2 to 11.6. A better solids destruction efficiency was observed at high pH's.

#### Scan 2

5        The effects of varying concentrations of caustic addition to TSS reduction and final pH with a 5:1 up-concentration were demonstrated, and are summarized in Figure 6. For all four samples, the final pH remained near 9.5 to 9.7. The addition of caustic appeared to have little effect on final pH, and did not show a favourable TSS reduction. One sample data had to be  
10       discarded due to analytical error.

It would appear that the dissolved solids within the CTMP waste activated sludge, when up-concentrated, have significant buffering capacities. Also, the tendency for carbon dioxide gas to be driven off causing a natural pH  
15       rise during the process, provides an adequate alkaline environment for cell lysis to take place.

#### Scan 3

20       The results of the STA simulation are summarized in Table 1. From the TSS and VSS numbers, it is apparent that a significant effect took place.

A key goal was met with the recovery of soluble nutrients, in the form of TKN (distillation method) and total phosphorous (colorimetric method, Hach DR/2000 Spectrophotometer, Loveland, CO). Analysis indicated the  
25       TKN of the product approached that of raw unfiltered digested biomass, and was much greater than the filtered, untreated WAS. A mass balance suggests that > 85% of the nitrogen within the biomass became available. This is appropriate since TKN consists of organic- nitrate- and ammonia-nitrogen fractions.

30

Total phosphorous also exhibited >90% recovery in the product, indicating that much of the previously inaccessible nutrients trapped within the

biomass were released. The presence of the increased soluble organic and inorganic nutrient concentrations could decrease additional nutrient requirements in conventional AST technology; the inorganic and organic nutrients are all potentially recoverable into the soluble phase.

5

Inorganic anions such as carbonates and sulphates exhibited significant reductions as well. This may be due to oversaturation of the inorganic salts during up-concentration, causing precipitation from solution .

10

The analytical survey indicates that there is excellent potential for the sludge treatment process to produce a distillate of very high quality while recovering virtually all the available nutrients that have been converted from the solid to the liquid phase.

15

It appears that a high quality distillate can be produced with COD levels of less than fifty (50) mg/l and conductivities less than 80  $\mu$ S/cm. Since >80 percent of the water in the original activated sludge sample was recovered as a high quality distillate with this process, the normally high volumes of low consistency sludge that is the typical by-product of AST should be sharply reduced.

20

The neutral pH of the resulting distillate, observed at 7.1, supports the potential for high quality (low COD, conductivity and neutral pH) distillate. The results signify that the bulk of the organic and inorganic components will remain in the product and not be carried over to the distillate.

25

Normal dewatered sludge dryness at most facilities processing a combination of primary and secondary solids is in the order of 15 to 30 percent solids. Removal of much of the secondary sludge from the belt press, leaving primary sludge as the main feed source should provide dramatic increases in final sludge dryness. Therefore, there should be significant reductions in final sludge volumes requiring further handling and disposal.

30

The terms and expressions which have been employed in this specification are used as terms of description and not of limitations, and there is no intention in the use of such terms and expressions to exclude any equivalents of the features shown and described or portions thereof, but it is  
5 recognized that various modifications are possible within the scope of the claims.



Table 1

Test Parameters (mg, 1 liter feed)	WAS Total	WAS Soluble	Product Soluble	% Solubilized	% Recover- ed
T.S.	9,400	3,040	9,400	0%	
T.S.S.	6,360		2,660	58%	
V.S.S.*	4,850		1,150	76%	
Biomass V.S.S.**	4,150		450	**89%	
COD		600	2,500		420%
TKN	400	13	355		89%
TP (PO <sub>4</sub> )	16.5	3	15.6		94%
Carbonate		2054	290	86%	
		782	455	42%	

product diluted 4.5 : 1 to original volume

\* Inorganic suspended solids estimated from 1993 yearly average mill data

\*\* Corrected for VSS in the primary solids carry-over

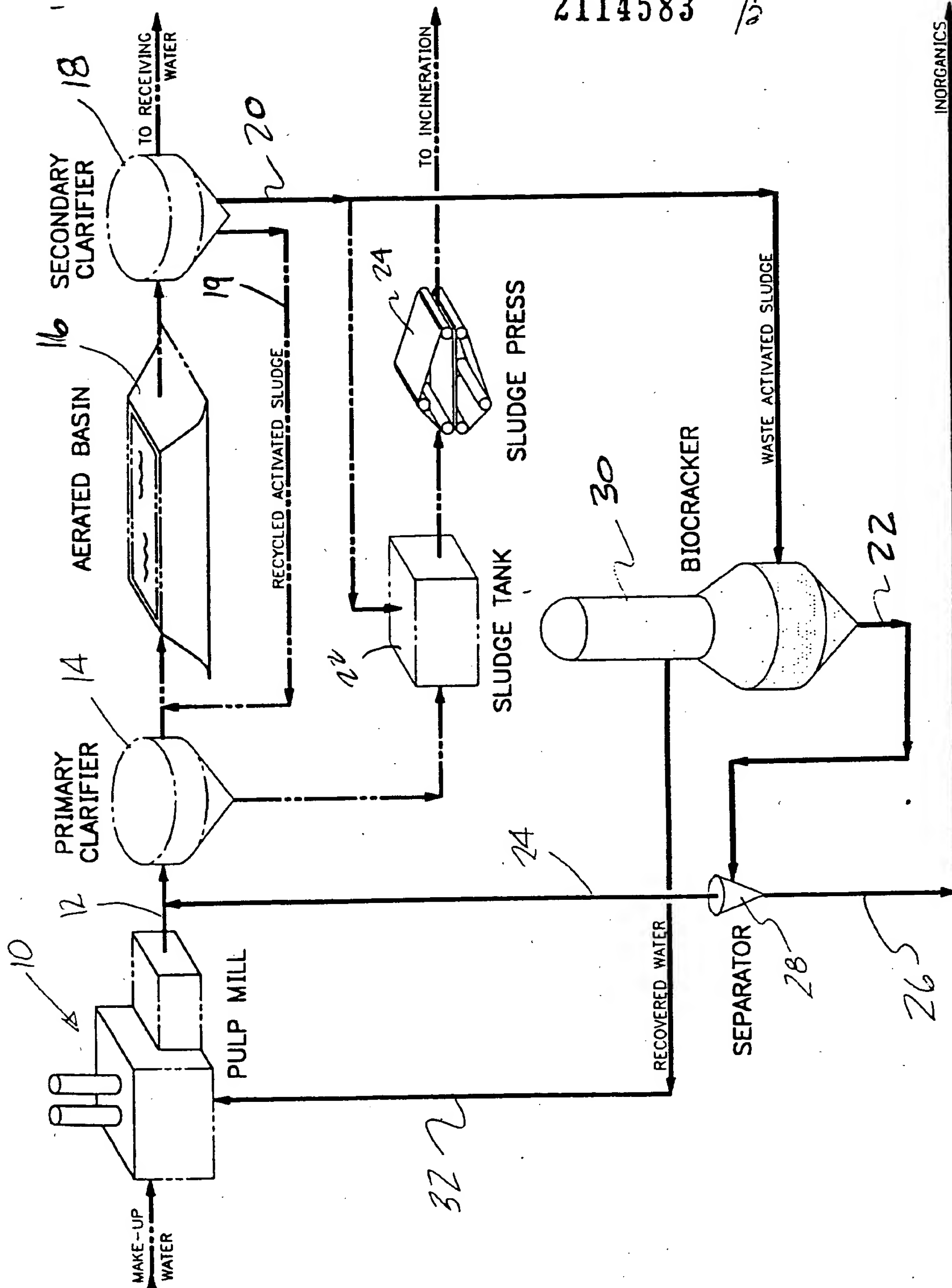


Figure 1

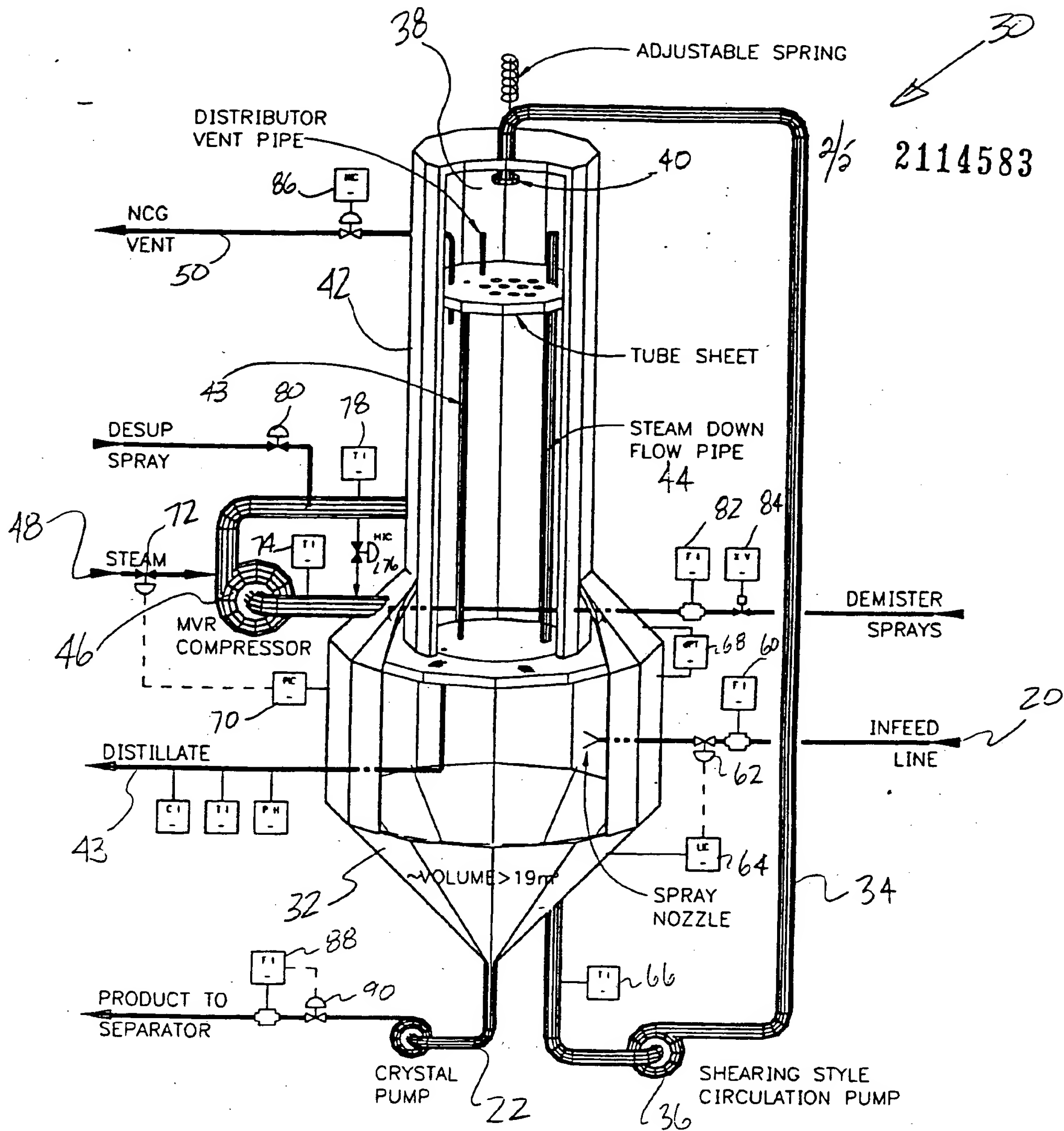


Figure 2

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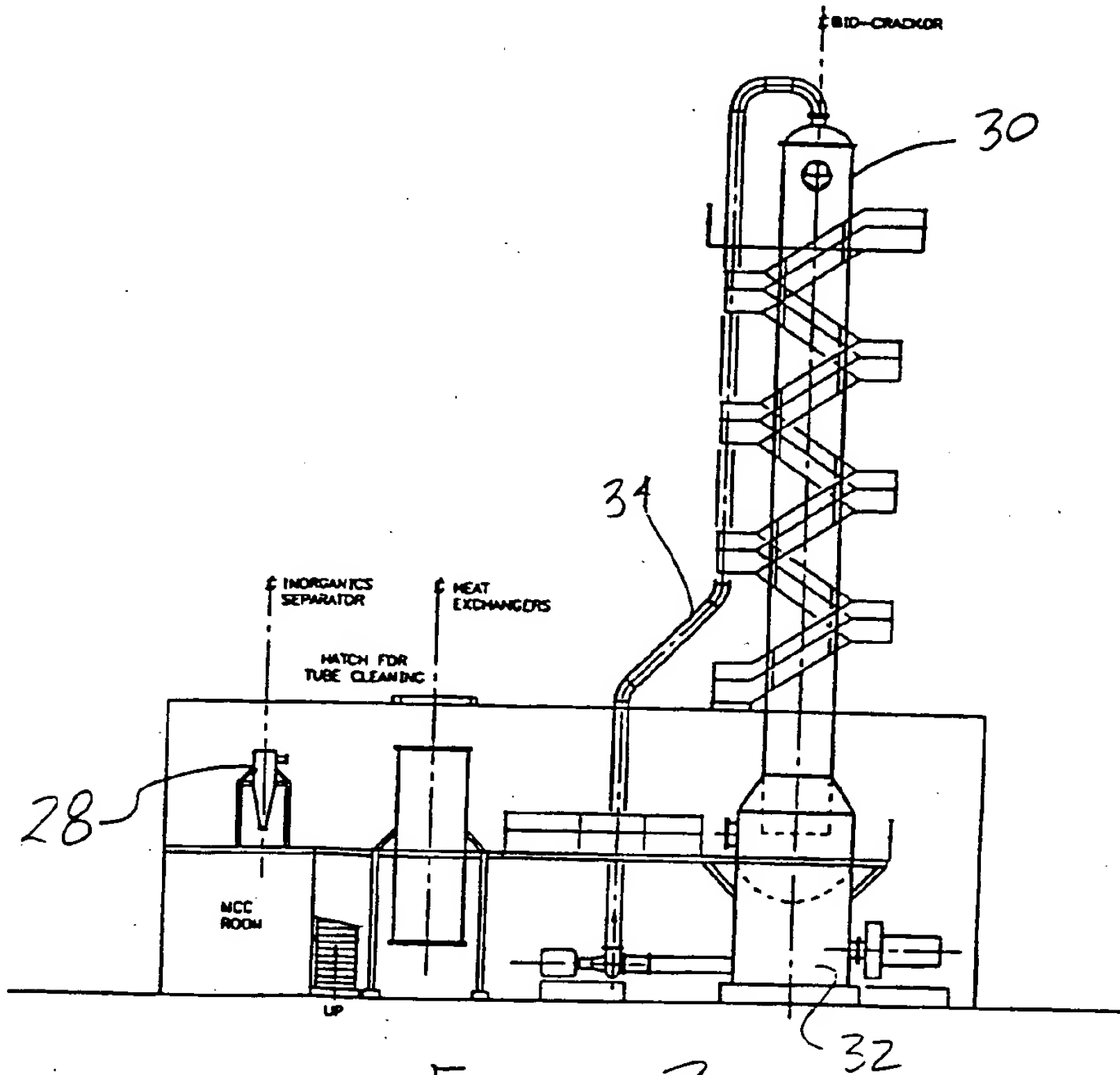


Figure 3

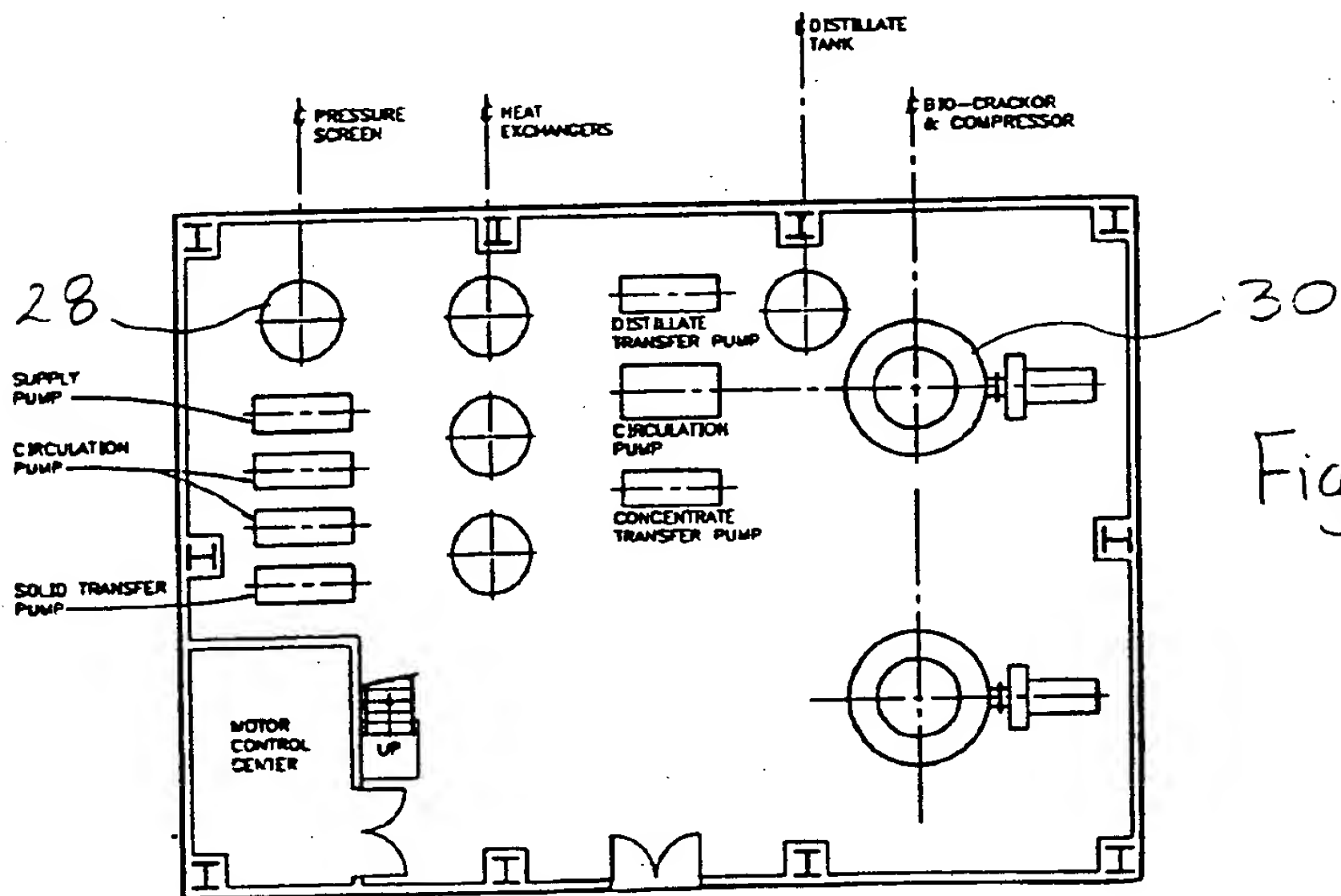
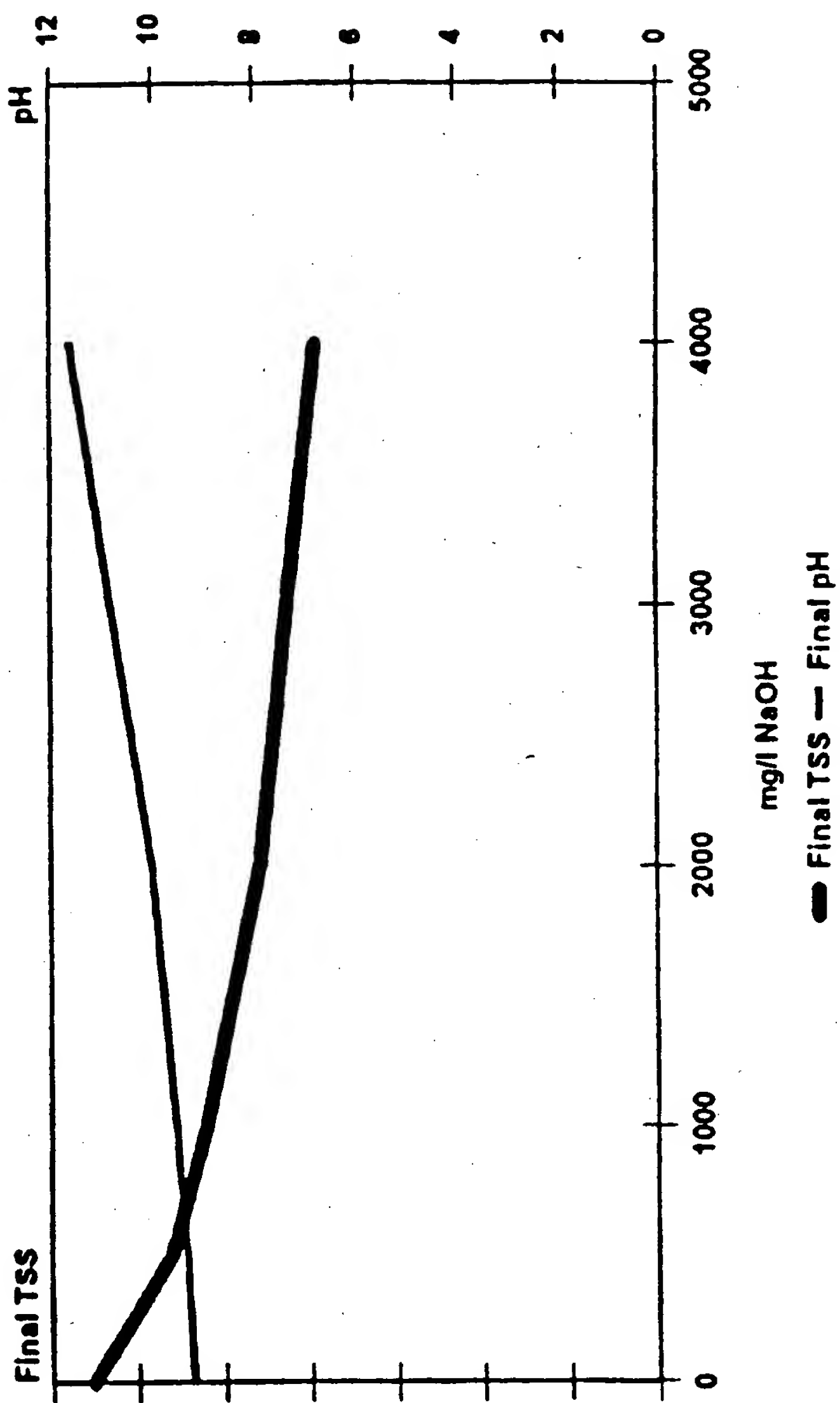
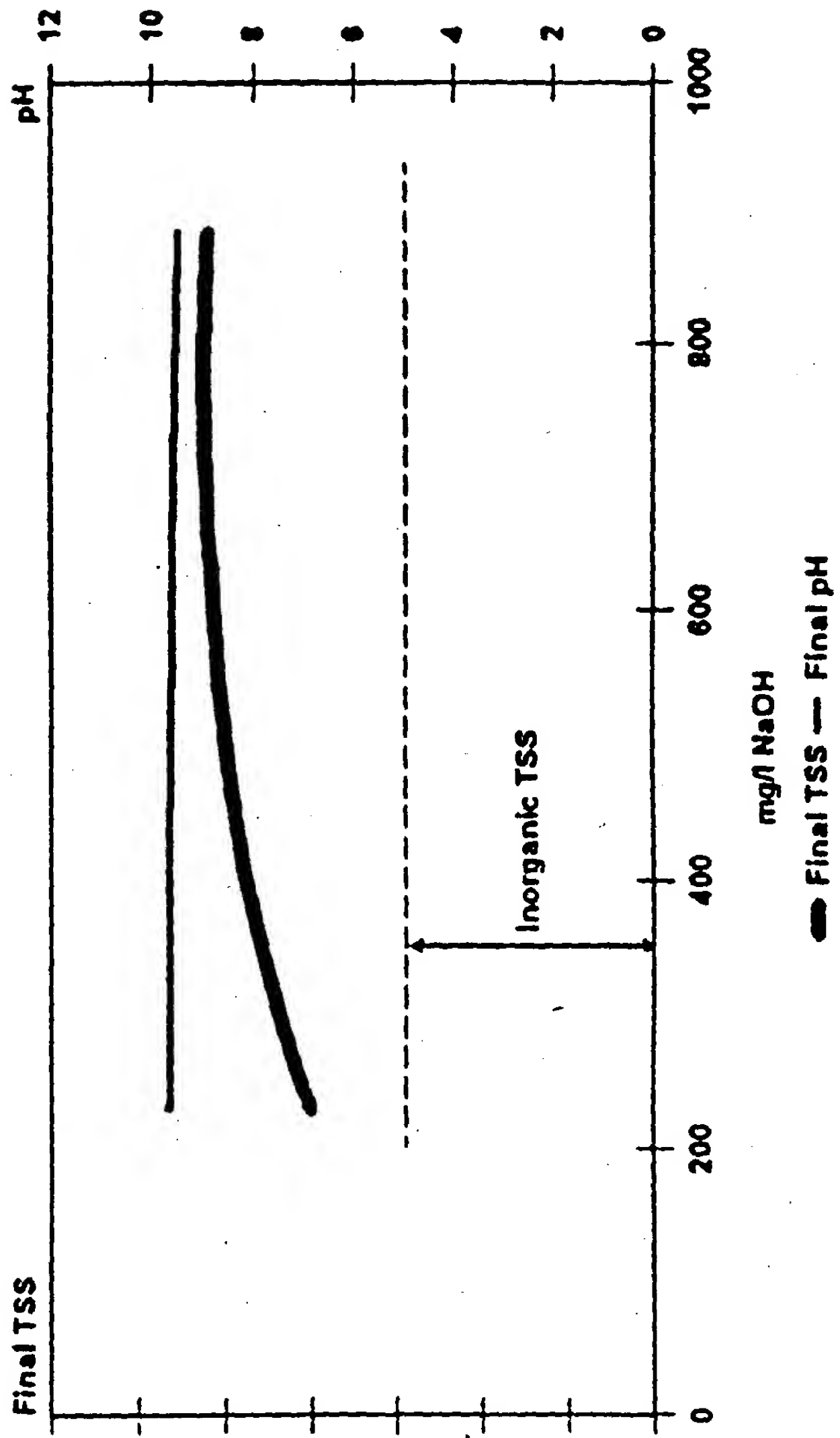


Figure 4



Scan #1, 2:1 volume reduction

Figure 5



Scan #2, 5:1 volume reduction

Figure 6

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**ABSTRACT OF THE DISCLOSURE**

5 A process and apparatus to promote rupturing and destruction of biological cell walls for solubilization of biological sludge is provided. The process involves concentrating a sludge above an initial concentration by an evaporation process at the saturation temperature for the operating pressure, and a high shearing process applied to the concentrated solids. The invention also provides an apparatus to promote rupturing of biological cell walls for the destruction and solubilization of biological sludge, the apparatus with an  
10 evaporation region for concentrating sludge, a shearing region for rupturing the biological cell walls, and a sump region for receiving a feed stream of sludge and discharging a dewatered product stream. The process also provides a retention time for the destruction and solubilization to take place and provides for the separation of water from the sludge for re-use.

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